APPENDIX A

Summary of Previous Characterization Work from CH2M HILL's Project Library Database

BACK TO TABLE OF CONTENTS

NEXT

Library #	Date	Document Name	Author	Purpose and Objectives	Study Area	Evaluation Methods	Key Observations with Respect to EPA's Mine Water Management Project	Other Relevant Findings or Suggestions from the Author
809	01-Jan-35	A Mineralogic Study of the Bunker Hill Lode at Kellogg, Idaho	Kroll, Egon H.	To make a detailed mineralogic study of the Bunker Hill lode, Kellogg, Idaho	Bunker Hill, from the outcrop to the lowest workings	Microscopic examination of polished surfaces and thin sections of specimens.	Description of fault locations based on USGS Prof. Paper 732.	
115	01-Dec-73	Solutions to Problems of Pollution Associated with Mining in Northern Idaho	Ralston, Dale; Trexler, Bryson Wai, Chien; Renison, William; Rickman, Francis; University of Idaho and Idaho Bureau of Mines and Geology	To investigate sources and causes of the acid mine drainage in the Bunker Hill Mine in order to provide information for prevention of continued drainage in this and other mines.	Bunker Hill Mine	A network of weirs and flow recorders were installed to investigate water quality and quantity in the upper country and in levels below 9. Recharge potential to the mine was investigated through the use of fluorescent dyes. Laboratory investigation of different ores was conducted to determine the mechanisms of acid production.	Low pH water occurs from 4 Level to 12 Level within the interconnecting stopes of the Flood-Stanly Ore Body (Bluebird Ore). A water loss of 18.6 acre-feet was observed between the West Milo weir and the Phil Sheridan weir (10/1/72 to 5/18/73). Dye tests showed direct connection between mainstem Milo and Small Hopes and Reed Tunnel (less than 1 hour lag time). Three potential recharge areas exist; caving area, old stopped areas near the Bunker Hill dam, and the Cate fault near main stem Milo Creek.	Laboratory leaching test showed that Zn, Pb, and Mn increase in the effluent with a decrease of pH, sulfate ions were found in the effluent of all tests, and that the leaching process slowed down when oxygen levels were reduced. This report is a summary of work performed from May 1972 to May 1973.
106	01-Dec-75	Sources and Causes of Acid Mine Drainage	Trexler, Bryson Ralston, Dale; Reece, Dennis; Williams, Roy	To document the controls, occurrence, movement, and quality of groundwater in and adjacent to a deep, hard rock mine.	Bunker Hill Mine	Same work as done under Ralston above. Data collected through September 1973.	60 gpm loss through the bottom of the Bunker Hill Dam. Interconnection established with dye tracer tests between Deadwood Creek through Inez Shaft and 9 Level. Flushing mechanisms present in Flood-Stanly Ore Body. Drill holes are another source of water inflow to the mine.	Recommendations for reducing recharge include allowing sediment buildup in Bunker Hill Dam, construction of an impermeable cutoff wall at the collector raises to the Phil Sheridan diversion constructed on Deadwood, and cap Diamond Drill Holes (DDHs).
116	01-Jun-75	The Hydrogeology of Acid Production in a Lead-Zinc Mine	Trexler, Bryson	Same as above.	Bunker Hill Mine	Same work as above.	Surface water recharge may account for 70 percent of the mine discharge. 20 percent is attributed to groundwater entering through fractures.	Same as above.
114	1980	Production of Acid Water in a Lead-Zinc Mine, Coeur D'Alene, Idaho	Wai, Chien; Reece, Dennis; Trexler, Bryson; Ralston, Dale; Williams, Roy	To investigate sources of acid mine drainage and methods for preventing pollution.	Bunker Hill Mine	Leaching tests (summary of tests done in #115), review of previous work.	Ore types can be classified into four groups: Group I (Newgard 5 Level, J Ore Body 17 Level, Francis Ore Body Level 22) produces a basic solution when exposed to water. Group II (March Ore Body, J Ore Body 20 – 22 Level) produces little effect when exposed to water. Group III (Flood-Stanly beneath caving area, 4 Level) produces a strongly acidic solution. Group IV (Small Hopes upper & lower ore bodies, Bluebird Ore similar to Flood-Stanly, Francis Ore Body Level 17 and 22) produce acid initially but then consumes it to give a solution that is neutral or basic. Acid water production is related to oxidation of pyrite and pyrite to calcite ratio in the rock. Rock with a ratio in excess of 0.6 should eventually produce acid.	Authors suggest that introducing lime or limestone into lower drainage ways of an acid-producing area is a possible way of minimizing the acid water problem.

NEXT

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523	01-Apr-82	Water Flow Patterns Within the Bunker Hill Mine, Idaho	Eckwright, Terry Alan	To describe the patterns of water movement and fracture with depth in a fractured metamorphic environment.	Bunker Hill Mine	Literature review, recharge investigation, water measurement on fourteen levels (9 Level to 27 Level) between July and August 1977.	Groundwater enters the mine through DDHs or mine workings that intersect water-bearing fracture systems. Ratio of discharge to drift length averages 0.009 gpm/foot.	More than 100 DDHs were observed flowing > 1 gpm. Some water from the direction of the Crescent mine is drained to Bunker Hill on 23 Level.
503	11-Sep-84	Analysis of Recharge to an Underground Lead-Zinc Mine, Coeur D'Alene Mining District, Idaho.	Hunt, Joel	To identify locations and mechanisms that control recharge to the Bunker Hill Mine in order to delineate reclamation procedures to reduce acid mine drainage	Milo Basin	A variety of field techniques were used including; a spring survey installation of piezometer nests dye tracing surface resistivity dye dilution on Milo Creek and South Fork Milo Creek hydrochemical analyses	Smaller springs are seasonal, suggesting that fracture flow systems generally do not carry large flows in the study area. Dye-dilution gain-loss studies do not support Trexler's findings of <u>significant</u> loss above Bunker Dam and South Fork confluence. Surface resistivity profiling showed that high resistivity on the West Fork in the vicinity of the Katherine fault may indicate that the fault is unsaturated in the area of the survey. Dye tracing did not verify the existence of short flow paths connecting mainstem Milo Creek to the Bailey Ore Chute or 5 Level drain, and failed to locate pathways of direct infiltration from West Milo Creek to "sites of known flow on the 5 and 9 Levels," but did establish a connection between West Milo Creek and Phil Sheridan (Raise No. 2, No. 3, and the drill hole). Nested piezometers indicate significant downward gradients (up to 1.75 ft/ft) in the vicinity of South Milo Creek and the main stem of Milo Creek.	Fault locations based on Bunker Hill Soils Anomaly Map, Bunker Hill Company, 1967. West Fork of Milo Creek is spring-fed ~2,300 feet upstream of Guy Cave Area. Detection of dye in the Phil Sheridan drill hole suggests that water underlying West Fork of Milo Creek moves through an intricate, diffuse fracture system, vertical groundwater velocities are estimated at 10 feet per hour. Approximately 1% of the total volume of injected dye was accounted for in the Phil Sheridan drill hole. Stream sections flowing northward or northeastward are more likely to intersect major fracture zones than stream sections with other orientations due to the general north-northwestern trend and southerly dip of most major faults. Katherine fault is located approx. 650' upstream from Phil Sheridan Raise No. 2. West Fork of Milo Creek diversion recommended. Fault dewatering with drill holes from Phil Sheridan also recommended.

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101	01-May-85	Delineation of Abandonment Procedures for the Bunker Hill and Crescent mines, Shoshone County, Idaho	Hampton, Kathleen	To investigate the application of alternative abandonment procedures to the Bunker Hill and Crescent mines. Specific objectives include: • Summarize classic abandonment procedures. • Describe physical and geohydrologic characteristics. • Describe recharge mechanisms. • Discuss potential effects of abandonment procedures.	Bunker Hill and Crescent mines	• Computer search of abandonment procedures. • Water sample collection.	• Infiltration control (surface sealing of fractures, streambeds, water diversions) mine sealing (dry, air, hydraulic), and in-mine diversions are typical abandonment procedures.	• Author suggests that if infiltration control is used solely to decrease the quantity of discharge at the Bunker Hill Mine, studies should be conducted on the economics of treating a lesser quantity of water that has a higher concentration of pollutants, as compared to treating a greater quantity of effluent that is more dilute.
108	01-Jul-85	Acid Water Implications for Mine Abandonment, Coeur d'Alene Mining District, Idaho	Riley, John	To identify and evaluate alternative reclamation procedures for controlling acid water discharge after the abandonment of the Bunker Hill Mine.	Bunker Hill upper country	• Literature review • Design and operate an underground monitoring network	• Bailey Ore Chute may receive recharge from the Katherine fault (near the junction with Marblehead fault) via DDH #1208 on 7 Level (and 7 Level Dam). • Dilution vs. flushing mechanisms are described. • Four sites (Stanly Ore Chute, Stanly X-cut, Cherry Raise, and 7 Level Drain) contribute more than 75% of the zinc load but only 3% of the flow.	• Author suggests a detailed understanding of the mechanisms controlling recharge to and flow within the Flood-Stanly Ore Body, which should be a high priority for research in order to successfully improve the quality of the water discharging from the mine.
107	01-Jul-85	Analysis of Water Movement in an Underground Lead-Zinc Mine CDA Mining District, Idaho	Erickson, Daniel	To identify and evaluate reclamation alternatives to reduce long term acid discharge from the Bunker Hill Mine. Specific objectives include: • Review the geologic and hydrologic information to develop a conceptual model of mine inflow. • Design and implement a mine water monitoring network. • Analyze discharge hydrographs to test the conceptual model and to identify sources and mechanisms of recharge.	Bunker Hill upper country	• Design and operate an underground monitoring network. • Hydrograph analysis.	• A hierarchical distribution of hydraulic conductivity is suggested (fractures in Cate Fault > fractures in other northwest-southwest faults (Katherine Fault believed to be largest contributor of these, pg. 77) > northeast-southeast faults > relict bedding planes). • Primary source of recharge intercepted by the Bunker Hill Mine is spring snow melt. • West Fork of Milo Creek is most probable source of water to the Stanly Crosscut and Stanly Ore Chute. • West Fork of Milo Creek to Katherine fault may be reduced by cutoff wall /diversion above the fault, and or dewatering the fault through drill holes or drifts from the Phil Sheridan. • Bedding planes and joints provide no significant inflow to the mine (pg 83 – contrary to Lachmar No. 506) • Surface contouring and sealing may be effective in reducing precipitation recharge to the near surface workings in the Flood-Stanly Ore Body between the top of the Cherry Raise and the Guy Cave Area.	• Workings on the 4 Level over the Becker Weir penetrate the alluvium of Milo Creek approximately 270 feet downstream from the Milo Creek Dam (aka Bunker Hill Dam). • Reclamation procedures will primarily result in the diversion of good quality water away from the mine. The remaining mine discharge will be of worse quality because there will be less water to dilute (pg 81). • Similar studies should be conducted for the Barney side.

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509	Jan-86	Application of Mathematical Modeling to the Analysis of Ground Water Flow Patterns Near a Deep Underground Mine	Frankel, Paul	• To gain a better understanding of the groundwater fluid potential distribution of the mine. • To utilize a numerical groundwater flow model to evaluate the relative importance of several major structural features on the fluid potential distribution near the mine.		• Literature review of previous work and available mathematical models. • Conduct modeling.	• A model could not be constructed to represent the details of the groundwater flow system because the present level of knowledge of the flow system is too limited. • Best fit values of hydraulic conductivity are 1.5×10^{-5} cm/sec for blocks and 1.5×10^{-3} for faults.	Suggested techniques to reduce inflow to the mine through fault zones: • Lining stream channels where faults zones occur, • Diversion away from faults, • Underground drainage of faults, • Grouting tunnel intersections with faults.
513	01-Jul-86	A Study of Groundwater Age in the Bunker Hill Mine, Idaho	Hartman, Mary J	To develop a better understanding of how groundwater age relates to depth and faulting in the Bunker Hill Mine, so that abandonment procedures can be tailored to the flow paths intercepted by the mine.	Surface water, 5 Level to 27 Level	• Literature review. • Mine recon to assess accessibility. • Groundwater sampling and analysis of isotopes (tritium, half life = 12.43 years) on surface and 5 Level to 27 Level.	• Relative contribution of pre-bomb (1953) water to the total flow of groundwater into the mine increases with depth. • No clear relationship between groundwater age and proximity of major faults is evident in the mine • Drill holes with low discharge rates tend to discharge post-bomb water (water that was present in the atmosphere after 1953) and holes with high discharge rates tend to discharge pre-bomb water (water that was surface water or infiltrated into the ground before 1953). Therefore, longer flow paths tend to be characterized by higher rates of flow (page 43, 45). • Both long, tortuous flow paths and short, direct flow paths exist in the vicinity of the mine.	• Author suggests that surface water diversions probably would have only limited effects on water quality because surface water recharge is probably not direct (note - based on sampling rock bolt water and drill hole water). • Author suggests that most promising abandonment plans appear to be a combination of grouting and underground diversions.
501	01-May-87	Rock Discontinuity Properties and Ground Water Flow in an Underground Lead-Zinc Mine, Coeur d'Alene Mining District, Idaho	Haskell, Kenneth	To study the influence of rock mass discontinuities on ground water flow to the Bunker Hill Mine as an aid to the development and evaluation of solutions to the acid mine drainage problem.	5 Level – New East Reed Drift, Mainstem Milo	Discontinuity mapping (scanline and cell surveys), characterization, and flow measurements, and statistical analysis.	• Relict bedding planes appear to be the primary flow paths through the rock mass. • Trace lengths display a significant positive linear correlation with the proportion of discontinuities that were observed to conduct water.	• Study may be biased because New E. Reed Drift does not cross any major faults.
512	30-Sep-87	Evaluation of Waste and Water Contamination for Closure of a Hard Rock Mine Complex (Quarterly Report – not a thesis)	Williams, Roy	Project C – To determine the relationship between poor water quality and bacterial activity	3 and 5 Levels	Bacterial culturing of samples collected from the underground locations on the 3 and 5 Levels	• Highly contaminated flow locations (West Reed Flume, Green House, Homestake Ore Chute, and Homestake 2R) gave high bacterial counts. Locations with low metals contamination (Reed Tunnel Flume, Becker Weir, Homestake Blue) gave low to very low bacterial counts.	• Project C – Underground Work by Jim Osiensky includes hydrogeologic evaluation of boreholes on New East Reed that may be of value.

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506	01-Feb-89	Analysis of Fracture-Flow Hydrogeology in an underground Lean-Zinc Mine, CDA Mining District	Lachmar, Thomas	To determine which man-made and natural features control groundwater flow through the mine, evaluate the applicability of several types of fracture-flow models, and gain understanding of fracture-flow hydrogeology to identify mitigative measures.	5 Level – New East Reed Drift.	• Scanline surveys, cell surveys, coring logs from drillholes. • Flow measurements from rock bolt, drill holes, and structural features. • Pressure measurements and flow testing at drill holes. • Nested piezometer measurements. • Modeling.	• Flow rates in eight tarps installed in the New East Reed Drift under rock bolts, drill holes, and structural features exhibit seasonal fluctuations. • Bedding planes appear to be the primary conduits for groundwater flow in the fractured quartzites of the Bunker Hill Mine. Bedding planes occur at or near the surface over virtually the entire Milo watershed, therefore recharge may occur over a much wider area than previously thought, and the contribution of individual sites identified by Trexler and Hunt may be relatively small (pg 158). • Water levels in piezometers probably reflect a shallow perched aquifer system, whereas pressure fluctuations in drill holes reflect the true potentiometric surface. (pg 103) • Agrees with Hunt - Surface water recharge from mainstem and South Milo is not as rapid as Trexler suggests (pg 157) [note: does not consider alluvial flow in South Milo.] • Surface water recharge directly to the mine is a major factor in the production of poor quality water. • Agrees with Hunt – inflow to the underground workings from the groundwater flow system (most of which would occur below 9 Level) may account for more mine water than sites of direct infiltration (pg 159). • Dewatering the major fault zones probably would not cause a significant reduction in the amount of poor quality water produced. Grouting faults and bedding planes, and diversion of West Milo may offer best hope for minimizing water inflow or recharge. • Fault infilling material (gouge vs. breccia) probably control the hydrogeologic character of the faults. Faults filled with gouge (33 or 36 in NERD) should act as barriers to flow.	• Good summary of previous hydrology work (pg 22 – 26). • No major faults intersect the New East Reed Drift, therefore the conclusions regarding contribution from bedding planes is biased. • Author suggests that it seems unlikely that the production of poor quality water could ever be halted completely. • Average hydraulic conductivity of fractured rock generally lies within 10^{-6} to 10^{-5} cm/sec.
118	01-Apr-89	Ground-Surface Delineation of Fractures that Appear to be Connected to Underlying Mined-Out Openings Using A Naturally Occurring Gaseous Tracer	Kirschner, Frederick	To study the occurrence of minor subsurface structural features that may constitute recharge pathways from unsaturated mountain slopes to underlying acid producing rocks.	West Milo drainage around Guy Cave.	Soil gas survey using CO2 as a tracer gas.	• Subsurface conduits that connect mined-out areas in the subsurface to the ground surface within the study area can be detected through soil gas surveys.	• Interesting cross section of Flood Stanly Ore Body (pg 16). • References Schwab (1952) who looked at the 3-dimensional boundary of the ore body. • The position of the Buckeye fault is observable on the eastern wall of the Guy Cave.

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524	01-Dec-89	Spatial Characterization of Geologic Structures and Ground Water Discharge in an Underground Lead-Zinc Mine, Coeur d'Alene Mining District	Whitbread, James	To map and describe pertinent characteristics of geologic discontinuities, leading to a better understanding of groundwater flow in discontinuous rock mass.	5 Level – New East Reed, Asher Drift, Russel Tunel.	Scanline mapping and cell mapping	• There appears to be a pattern of fracture wetness associated with the Dull and Sullivan faults. Areas of low fracture wetness are located in hanging or southwest walls of the Dull and Sullivan faults. As the distance in a southwest direction from the faults increases, the proportion of wet fractures increases until the next successive fault is encountered (pg 89). • Fault structures contain gouge filling, most likely allowing groundwater flow primarily in directions parallel to faults.	• Larger scale investigation than that conducted by Lachmar and Haskell.
121	01-Dec-89	Near-Surface Acid Mine Water Pools and their Implications for Mine Abandonment, Coeur D'Alene Mining District.	Bretherton, Bart	To describe the temporal, physical, and chemical characteristics of pooled water in the Homestake workings	3 Level Homestake Workings	• 24 Monitoring sites (15 in Homestake, 4 on Cherry 4, 5 on 5 Level Reed) consisting of flumes and tarps. • Condensate samples from evaporation pan. • Bacterial sampling.	• Significant production of acid water occurs in the very near surface workings (Homestake) over the Flood-Stanly Ore Body. • Metals are transported by the vapor in the water saturated mine exhaust air • Fractures in the Homestake first flowed towards the end of the workings, then progressively appeared towards the center of the workings. The arrival of peak fracture flow at sites 500 and 700 feet from the end of the workings was separated by two to three weeks. • The intersection of the Cate fault with South Milo and the intersection of the Buckeye fault, Guy Cave, and Utz workings are two important sources of recharge to the Homestake.	• Provides a cross section of the 1000 NW that shows interpretation of the surface expression of the Flood Stanly Ore Body extending from the Buckeye fault to a location between the Cherry Raise and the Sullivan fault (pg 101).
505	01-May-90	Analysis of the Hydrogeologic Role of Geologic Structures with Application to Acid Mine Drainage Abatement	Levins, Russell	To investigate the role of geologic structures and fractures in controlling ground water flow into the mine. Specific objectives include: • Develop a hydrogeologic conceptual model, • Implement a hydraulic testing program, • Interpret results relative to conceptual model.	5 Level – New East Reed Drift (continuation of Lachmar's work)	Packer tests (single and double packers) in drill holes in the New East Reed Drift.	• The results of reconnaissance level hydraulic tests show that the majority of water that discharges from the five underground drillholes is derived from two or three short intervals in each drillhole separated by large intervals of rock that produce little water. • Clayey gouge associated with McGatlin Fault probably constitutes a relatively continuous hydraulic barrier in the groundwater flow system. Where gouge is absent, northwest trending faults may comprise positive recharge boundaries.	• Author suggests that on the largest scale the major northwest trending faults probably control the overall pattern of mine water inflow within the mine. Fold related structures like those observed in the New East Reed Drift probably control water inflow patterns on a more local scale. • Author suggests that a detailed evaluation of geologic structures found in the vicinity of acid producing areas will be necessary prior to the adoption of final acid mine drainage mitigation procedures such as grouting.

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516	01-Jun-90	A Comparison of Multivariate Statistical Analysis and the Use of an Indicator Ion for the Interpretation of Water Quality Data	Riley, John	To compare and evaluate the relative advantages of the use of selected multivariate statistical techniques and the use of single indicator ion in the interpretation of groundwater data from the Bunker Hill Mine.	Upper country – 9 Level and above.	Field monitoring, sample collection and analysis (January 1983 to December 1985), and interpretation of water quality characteristics.	• Five sites (West Reed Flume, Cherry Raise, 7 Level Drain, Stanly Ore Chute, Stanly Crosscut) constitute 3 percent of mine discharge and 76 percent of zinc load coming from the mine. The source of water for all of these locations is the Flood Stanly Ore Body. • Flood Stanly Ore Body extends from land surface near the collar of the Cherry Raise downward to between 11 and 12 Level. Stopes on 12 Level connect to the March Ore Body. • Flushing of acid reaction products from drifts, stopes, and pools is the primary mechanism for the introduction of dissolved metal into the mine water flow system. Dilution of poor quality water by good quality water is much less prevalent. • Reduction of mine water inflow that reaches specific acid producing areas would significantly improve mine water quality. Reduction of inflow would have little effect on the zinc load discharging from the mine unless the reduction of inflow decreases the flushing mechanism. • The use of carefully selected multivariate statistical techniques constitutes a significant improvement over the use of an indicator ion in the identification of complex chemical interactions in a contaminated groundwater flow system.	• These five sites are included in the current monitoring network as 5WR, 9CR, 9SO, 9SX, and 9SX2. • Author suggests DDH #1208 on 7 Level is major source of water to the Bailey Ore Chute. Remaining water at Bailey Flume is from exploration drill holes at the end of the drift. • Author suggests underground maintenance (eliminating muck piles, drift undulations, and other sources of pooled water) would decrease residence time and improve water quality by an unknown amount.

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510	01-May-91	Analysis of the Sub-Regional Influence of Geologic Structures on Ground Water Flow in Acid Producing Metamorphic Rocks	Demuth, Hal	To evaluate the influence of geologic structures on ground water flow on sub-regional and local scales, and to apply the results to an analysis on a regional scale. This work is an extension of Leven's work to evaluate a larger area which includes the Cate Fault, and to analyze the spatial influence of major geologic structures between 5 level and land surface.	5 Level and surface	Hydraulic testing of DDH on 5 Level – New East Reed Drift, and of a surface drill hole.	• Zone of disturbance associated with Cate Fault is 30 to 90 feet wide, McGatlin Fault is 40 feet wide. • Amount of gouge material in a fault depends on the magnitude of displacement along the fault and type of rock. Gouge distribution is more commonly higher in the footwall side of a fault. Gouge development is limited in small structures with little displacement. • Hydraulic conductivity of fractures in the hanging wall is commonly orders of magnitude higher than in the footwall. Hydraulic conductivity of small faults with limited displacements exceeds that of larger structures on a local scale. Gouge associated with larger faults may reduce horizontal hydraulic conductivity; therefore, adjacent northwest trending fault blocks may have different hydraulic head values. • Groundwater flow occurs downward through the fractured fault zones toward the mine workings (in a NW direction). • Smaller east-west trending structures may represent significant hydrogeologic features, but only on a local scale. The major faults, which extend spatially throughout the study area, probably provide a significant portion of the groundwater inflow to the mine on a regional scale. • Long term data shows similar pressure response along the length of drill holes. This suggest that surface streams, such as Milo Creek, are not the predominant recharge source for the ground water system in the vicinity of the mine. If this were the case, the temporal pressure response would vary along the drill holes between fault blocks.	• Author references Hobbs (1965, pg. 64) – deformation preceded sculpting of the present landscape sufficiently long ago that none of the original irregularities are reflected in the topography today; no fault scarp or fold can be traced by its surface expression. • Author suggests that runoff from short, intense events such as summer thunderstorms do not infiltrate the fractured bedrock system to the same degree as recharge events of longer duration (spring snowmelt). It appears that most of the water provided to the fault-controlled fracture system derives from groundwater infiltration, rather than from direct fracture connection to the surface streams. • Hydraulic conductivity across (through) the faults zones appears to be low. Research of Morrow and other (1984) shows that hydraulic conductivity of the gouge in fault zones is on the order of 10^{-10} ft/day (3.5×10^{-14} cm/sec). • Author suggests that diversion of groundwater from acid producing areas is the best method to reduce acid drainage. Suggests fracture grouting through drillholes.

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517	12-Oct-97	Ideas on Milo Creek Remediation Alternatives	Ralston, Dale; U of I	To provide ideas on the remediation work within Milo Creek drainage.	Bunker Hill—Upper Country	Analysis of existing information	• Increased mine discharge reported by Mr. Hopper is likely due to 1) greater than average precipitation after an extended period of lower than average precipitation, 2) changes in the Milo Creek channel in the reach from the water supply dam to the Reed adit, and/or 3) changes in underground workings including collapse or alteration of near-surface workings. • Most viable remediation projects are 1) Milo Creek diversion on mainstem groundwater in the alluvium as well as surface water must be diverted to be effective, and 2) improve Phil Sheridan diversion system by cleaning raises, assessing and repairing leaks in the drift, installing grout cutoff walls at the diversions, and piping or ditch diversion flow from the adit to the mainstem.	• Author suggests hydrologic evaluation of KT with respect to surface water flows to document changes in the mine discharge reported by Mr. Hopper. Also suggests water quality comparison of recent KT vs. past KT including metal concentration and loading. • Author suggests an underground recon of workings below the creek (Small Hopes, Reed and Russell areas) to assess potential increase in flow.
606	26-Aug-98	References for Bunker Hill Mine Project	Ralston, Dale; Riley, John	Provides a reference list for the Bunker Hill Mine Project.	Bunker Hill Mine	References by category (Hydrologic studies, Geologic, Treatment process studies, General,	• Presents list of references for the following areas concerning Bunker Hill Mine: Hydrogeologic Studies, Geologic Studies, Treatment Process Studies, General References on Abatement of AMD Problems.	
2011	Sep-99	Bunker Hill Mine Flood-Stanly In-Mine Reconnaissance Report	CH2M HILL	Identify surface water and groundwater recharge mechanisms and acid producing areas, understand mine water flow paths, identify missing hydraulic and metal loads identified during CH2M HILL mine water monitoring program.	Bunker Hill Mine Water – Flood-Stanly Ore Body	Underground field reconnaissance, field measurements of specific electrical conductivity	• Flow within the Flood-Stanly Ore Body consists of complex combination of low gradient ditch flow, steeply dipping manmade structures, and/or collapsed ground. Ponding occurs in undulations in drifts. Pyrite is ubiquitous in and around the ore body. Recharge controlled by localized heating in near surface workings and low and high elevation snowmelt.	• Substantial portion of the workings are inaccessible; direct modifications of accessible workings may have only a limited benefit of acid production and metal transport on the whole.
2013	15-Nov-99	Field Reconnaissance of Inflow/Recharge Mechanisms	CH2M HILL	Investigate recharge and surface water inflow features that provide a mechanism for water to flow into the mine and contribute to the generation of AMD.	Milo and Deadwood Basin overlying the Bunker Hill Mine.	Visual inspection	• Several recharge/inflow mechanisms were identified and very rough estimates of flow contribution to the mine were made. These mechanisms could be mitigated through a variety of methods.	
2006	Jul-99	Bunker Hill Mine Water Presumptive Remedy	CH2M HILL	Summarizes the initial presumptive remedy for long-term management of the Bunker Hill AMD. This document was used as part of the RI/FS for the mine water. It provides technology screening and development of the major components of a remedy, including AMD mitigations, AMD collection, AMD conveyance, AMD storage, AMD treatment, and sludge management. Some of the document findings were updated and/or modified through the subsequent RI/FS document.	Bunker Hill Mine Water	Engineering Analysis	• The document approach was to initially brainstorm a "presumptive remedy", then collect information needed to confirm, modify, or fill-in data gaps. The presumptive remedy was then refined. This document summarizes that process. • The document findings were used as part of the RI/FS for the mine water. Some were modified/updated during preparation of the RI/FS	

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2005	Jul-99	Acid Mine Drainage – Bunker Hill Mine Water Conceptual Model	CH2M HILL	Provides a review of existing information on flow and quality of water within the mine, summarizes the1998/1999 mine water sampling program that was implemented to document changes over approximately the past 15 years, summarizes known flow paths within the mine, and identifies current sources of poor quality water.	Bunker Hill Mine Water	Review of current and previous data collected on mine water flow rates and quality.	• Water inflow to the mine occurs from direct interception of surface water to the workings, recharge to the local groundwater system, and submerged workings. Intra mine flow is complex and not fully understood. The historical database indicates that the three biggest contributors of zinc load are 9SO, 9CR, and 9SX, which monitor discharge from the Flood-Stanly workings.	• Continuation of the 1998/1999 sampling program will provide valuable information on the current mine water characteristics relative to previous studies.
2020	22-Jul-99	Field Reconnaissance of Hanna Stope	CH2M HILL	Gain a better understanding of the underground conditions, configuration, and characteristics of the Hanna Stope to evaluate its potential for use as an underground depository for waste sludge	Hanna Stope	Underground reconnaissance, Sample collection and analysis.	• Access from the older workings to the west side of the stope is not available, little is known about the interconnections between the stope and the Hall and Williams Raise. Additional investigation would be necessary to identify and systematically plug all access to the stope for use as a depository.	
2017	1-Feb-00	Supplement No. 1B—Bunker Hill Mine Conceptual Model—Final Data Summary for 1998/1999 Monitoring Program	CH2M HILL	Presents, summarizes, and interprets the data from the in-mine monitoring program conducted in 1998/1999. Presents mass balances for flow, zinc, and lime demand for flow areas within the mine.	AMD within the Bunker HILL Mine	Underground flow monitoring and sample collection for many different locations. Development of mass balances.	• The in-mine flows and chemistry was similar in 1998/1999 as compared to 1983/1984/1985. • Located monitoring locations that can be used to evaluate the performance of mitigations.	
2018	7-Feb-00	Hydrologic Evaluation for Bunker Hill Mine TMDL Compliance	CH2M HILL	Evaluate the relationship between Kellogg Tunnel and SFCdA River flows to help develop selection and design criteria for mine water management systems that comply with upcoming TMDL requirements.	Kellogg Tunnel and SFCdA River	Historic hydrograph assembly and evaluation.	• There is not a good correlation between KT and SFCdA flow at the Pinehurst gauge.	• Additional modeling is necessary to evaluate the interrelationship between the mine water management components and the TMDL requirements.

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